ERDC/CHL CHETN-IV-43
June 2002

US Army Corps of Engineers

SHOALS Toolbox: Software to Support Visualization and Analysis of Large, High-Density Data Sets

by Jennifer M. Wozencraft, W. Jeff Lillycrop, and Nicholas C. Kraus

PURPOSE: The Coastal and Hydraulics Engineering Technical Note (CHETN) described herein outlines the capabilities of SHOALS Toolbox, a stand-alone software package designed to facilitate the use of SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) and other high-density survey data in engineering analyses. The SHOALS Toolbox comprises a suite of tools with which to visualize, manipulate, and analyze SHOALS data, in keeping with current U.S. Army Corps of Engineers (USACE) computer and engineering analysis standards. The SHOALS Toolbox is available free to all USACE elements and their contractors.

BACKGROUND: SHOALS is an airborne laser system that makes water-depth soundings (Figure 1). The laser is collimated red (1,064 nanometers nm) and green (532 nm) light pulsed at a rate of 400 Hz. A scanning mirror directs each laser pulse toward the sea surface and into the forward flight path of the aircraft. Receivers in the aircraft detect the return of each pulse from the sea surface ("specular interface reflection," Figure 2) and sea floor ("diffuse bottom reflection" and "reflected bottom signal," Figure 2). These returns are analyzed to determine water depth or land elevation for each laser pulse. Each measurement is geo-positioned using either pseudo-range or carrier-phase GPS techniques. The result is an XYZ data set containing measurements spaced approximately 4-8 m apart and covering nearshore land elevations through water depths as great as 60 m.

The SHOALS Toolbox enables data users to integrate SHOALS and other high-resolution data into engineering analysis and numerical models with speed and ease. The value of SHOALS data, particularly its complete coverage of the coastal zone with closely spaced points, is often lost due to lack of computer power, lack of tools with which to visualize and analyze the data, and unfamiliarity with the added information this type of data can bring to an engineering study. The SHOALS Toolbox enables visualization, manipulation, and analysis of high-resolution and dense data sets, maintaining current USACE computer and engineering analysis standards. The simplicity of the SHOALS Toolbox operations promotes analysis of valuable data in engineering studies.

Figure 1. SHOALS system mounted on Twin Otter

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **SHOALS Toolbox: Software to Support Visualization and Analysis of Large, High-Density Data Sets**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,Vicksburg,MS,39180**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

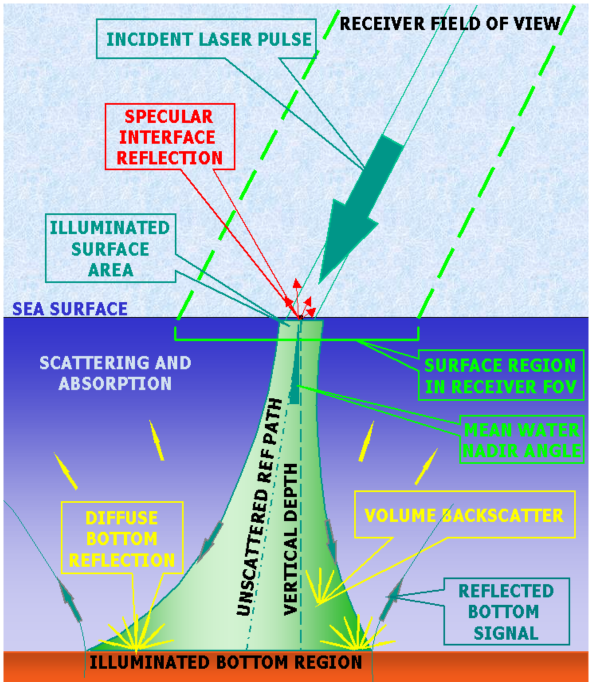


Figure 2. SHOALS operating principle

The SHOALS Toolbox comprises two modules of the Surface-Water Modeling System (SMS), a software package funded by USACE and developed at Brigham Young University's Environmental Modeling Laboratory. SHOALS Toolbox is available as a stand-alone product, or as part of the more extensive SMS package, which includes the ADCIRC, STWAVE, RMA2, and SED2D numerical models.

CAPABILITIES: SHOALS tools are divided between the scatter and map modules of SMS. The scatter module contains all tools related to the visualization or manipulation of XYZ data. Scatter tools include several methods of data decimation, coordinate conversion, and calculations such as vertical datum shifts and volumes. The map module contains all tools related to feature-type data like existing beach profile lines and imagery. Map tools include profile extraction; navigation channel and beach-fill design input and analysis; and image georeferencing.

Data Import. SHOALS Toolbox contains a flexible, capable, and convenient import interface specifically designed to manipulate spatial data. Similar to the Microsoft's Excel interface, it allows for space, tab, comma, or user-specified character-delimited files. The user specifies at which row in a file import will begin, which provides maximum flexibility for header lines in a file. SHOALS Toolbox imports any number of Z values associated with any XY, allowing for storage of additional information with each depth value.

A sample data import dialog is shown in Figure 3. The columnar data shown in the bottom portion of this figure is SHOALS data in the format that is exported from the SHOALS post-processing system. In the left portion of the figure, the user is specifying which columns are easting, northing, and elevation. In the central portion of the dialog, the user can specify additional values to be associated with each point. For example, column 2 of this file is the time stamp of each lidar shot. This time stamp can be imported with the depth values for each point.

Several SHOALS tools are available at import, including all forms of data decimation, coordinate conversion, and metadata import. A Triangulated Irregular Network (TIN) surface is automatically created from data at import. Surface creation is not a separate step in SHOALS Toolbox.

Data Visualization. The data visualization capability of SHOALS Toolbox takes data users beyond simple hydrographic and topographic charts that show only soundings or contours. Users can select the means of viewing data as points, contours, or depth values. Users can also select to view the triangulation of the data and the boundary of the data. Three types of visualization are shown in Figure 4: points colored by depth, contours colored by depth, and scalar values colored

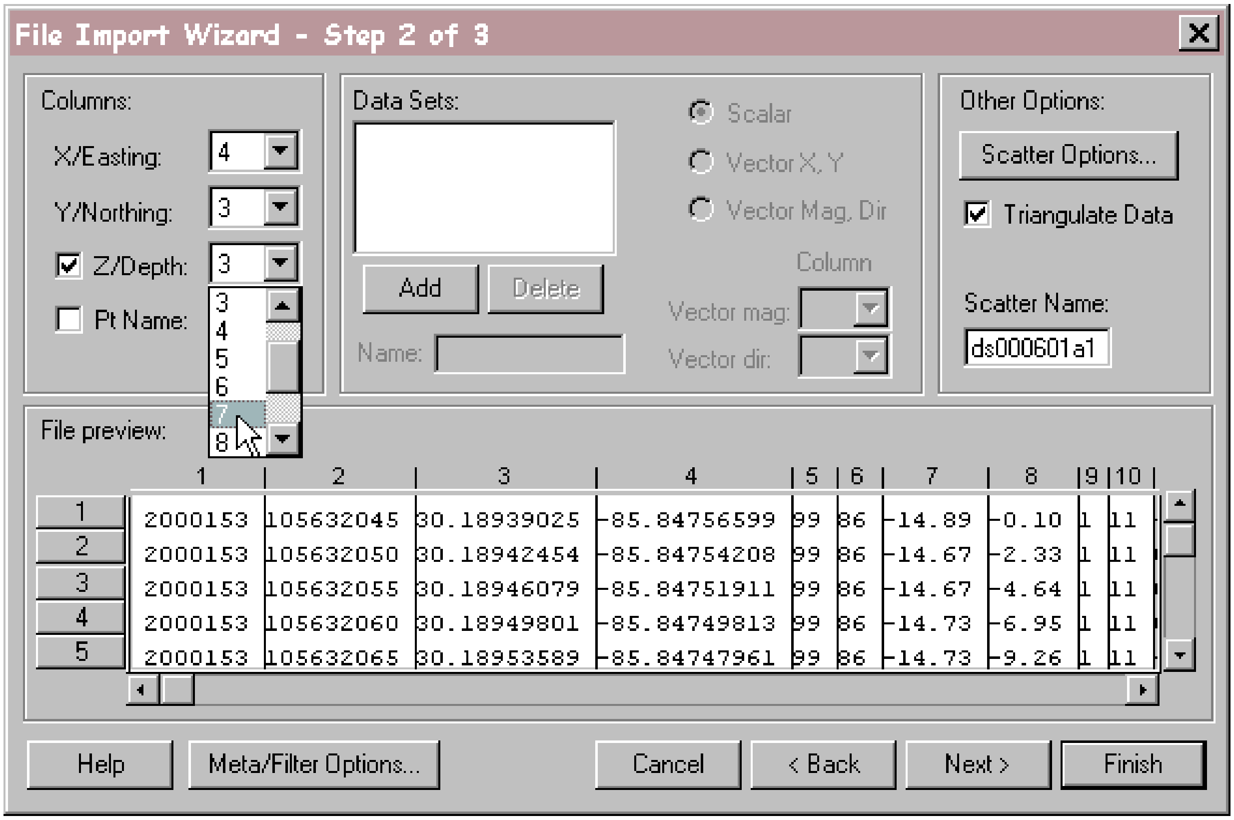


Figure 3. Sample data import dialog box. This box allows the user to specify which columns are easting, northing, and elevation. The user can also specify additional values to be imported for each XY value

by depth. Another visualization is shown in Figure 5, where an aerial photograph is overlaid with color-filled contours of SHOALS data collected at East Pass, FL. The most recent addition to SHOALS Toolbox visualization tools is three-dimensional rendering of the SHOALS data.

Edit Triangles. SHOALS Toolbox has many options for controlling the triangulation of data points, including a powerful manual editing tool. There are user preferences for maximum triangle edge length and interior angle that provide a first cut at creating an accurate triangulation. The manual editing tool allows the user to delete unwanted triangles, swap triangle edges, and create new triangles. Together, the preferences and manual tools allow the user maximum efficiency and flexibility in shaping the triangulation as near to reality as possible.

Data Decimation. Loading several SHOALS surveys into a computer program is challenging. Performing volume computations between two or more sets is impossible, even with recent advancements in computer processor speed. Some form of data manipulation is required to reduce the surveys to a manageable size before proceeding with the volume computations. Three common routines to reduce the size of a survey are deleting duplicate points, binning, and slope decimation.

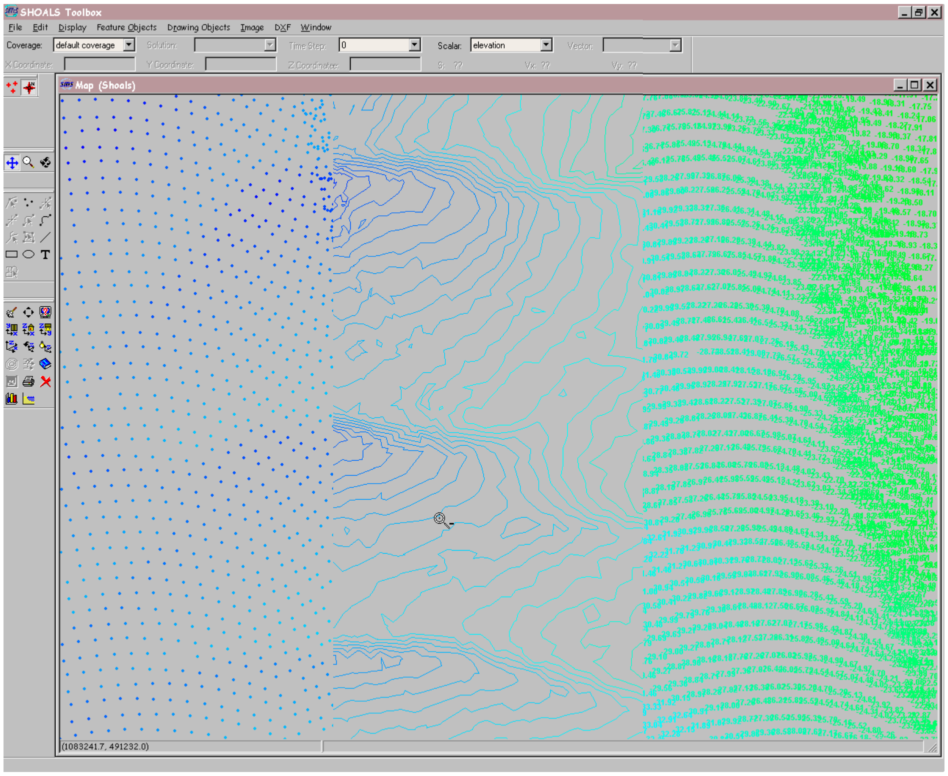


Figure 4. Examples of data visualization in SHOALS Toolbox: points, contours, and depth values, all color-coded for depth

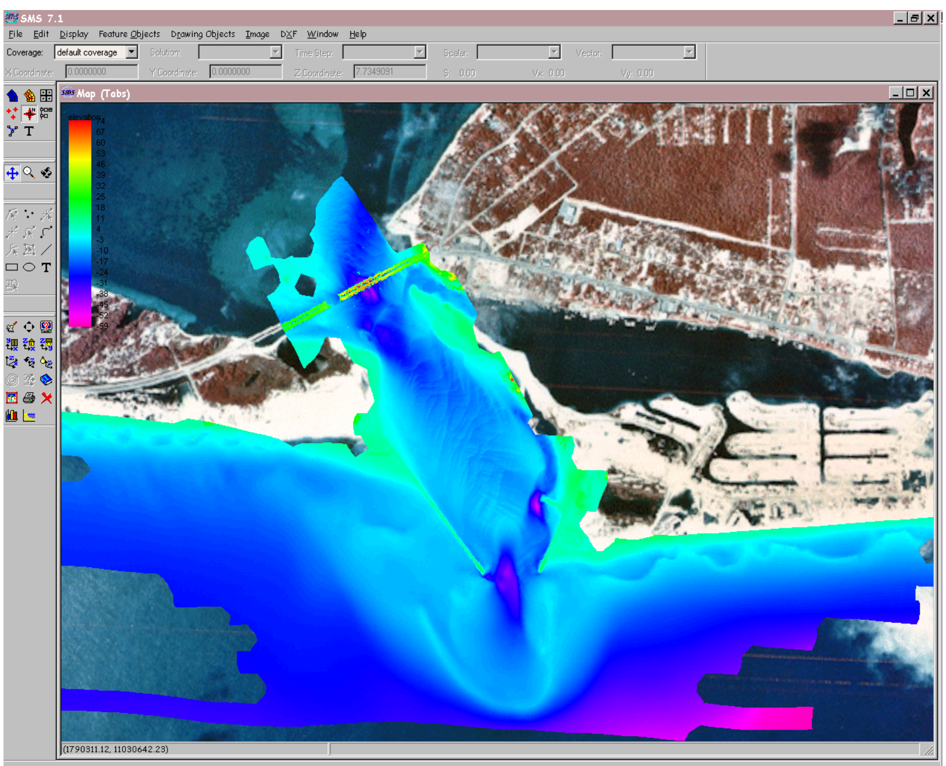


Figure 5. Example of data visualization in SHOALS Toolbox: color-filled contours overlaying georeferenced aerial photography

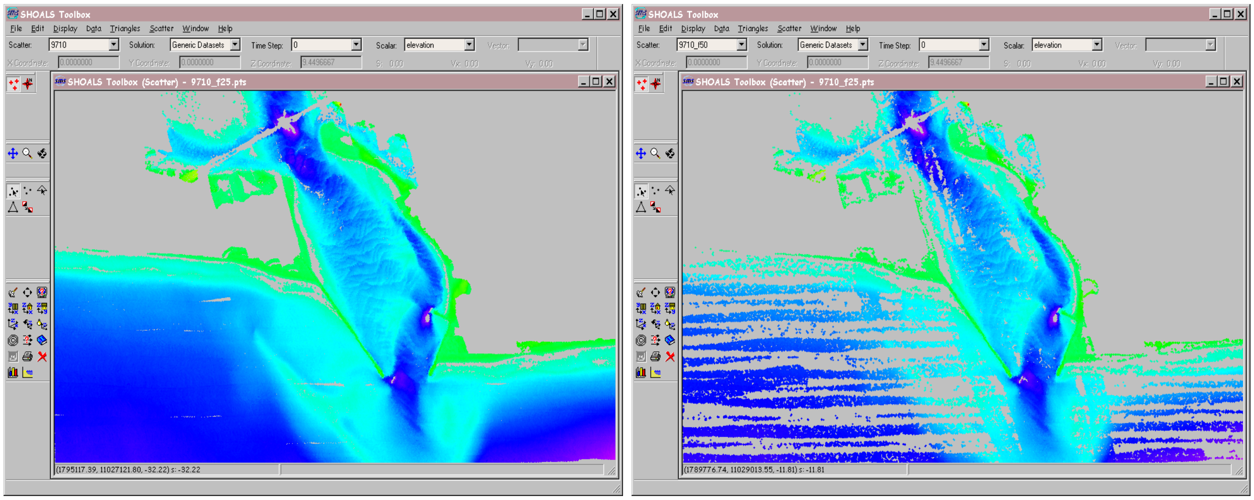
Deleting duplicate points is the least computer power/memory intensive and least intelligent means of reducing data set size in SHOALS Toolbox. As each point is read in, the program determines if it falls within a user-specified horizontal tolerance of points already accepted by the program. This method provides evenly spaced coverage, but there is no consideration of the vertical value of the data points.

Binning requires user-specification of a grid to overlay the data. Within each user-specified grid cell, a minimum, maximum, and average value is calculated. The user can decide to use the set of minimums, maximums, or averages calculated for each cell, keeping in mind that the averages are not real survey points, but a calculated value whose geographic location is reported at the center of the grid cell. The minimums and maximums found in each cell retain their original XY location.

Slope decimation is the most comprehensive means of reducing data sets size, because it considers the shape of the surface created from all data points. In slope decimation, the user specifies an angle. If the slope of the surface around any given point exceeds that angle, the point is retained in the reduced surface--otherwise the point is discarded. By retaining more data in areas where the surface is highly variable, like navigation channels or coral reefs, and less data where the surface is flat, like low-sloping beaches, slope decimation works specifically to preserve the integrity of the original data surface.

An example of data sets created using slope decimation is shown in Figure 6. Figure 6a shows 100 percent of the points collected by the SHOALS system at East Pass, FL. Figure 6b shows 50 percent slope reduction in the number of points collected at the site. Note the majority of the retained points are in the navigation channel, which is marked by sand waves that make the bathymetry in that area quite variable.

Data Interpolation. Data interpolation plays an important role in SHOALS Toolbox for volume calculations, grid creation, and profile extraction. Several interpolation methods are available. Linear interpolation is based on the TIN surface formulated previously and refined by the user. Inverse distance weighted method weighs values based on their distance from the XY coordinate requiring an interpolated value. Nearest neighbor method assigns the value of the nearest point to each XY requiring an interpolated value. Values can be interpolated from one SHOALS survey to another, from a SHOALS survey to a grid, and from a SHOALS survey to points along a profile line.



a. 100 percent of points collected by SHOALS system at East Pass, FL

b. 50 percent slope reduction in number of points collected at site

Figure 6. Example of slope decimation using SHOALS Toolbox. Note majority of retained points are in navigation channel, which is marked by large-scale sand waves that make bathymetry in that area quite variable

Data Calculator. The data calculator gives users the capability of performing arithmetic calculations on any value associated with a data point. Examples are an informal conversion from English to metric units, vertical datum calculations, and elevation changes between surveys. Elevation change computations are accomplished by interpolating from one SHOALS data set to another and then subtracting. After the less recent elevation values are subtracted from the more recent elevation values, a negative number indicates erosion, whereas a positive result indicates accretion. An example plot of elevation changes calculated between the 1997 and 2001 surveys at East Pass, FL, is shown in Figure 7. Blue indicates areas of accretion while green and yellow are areas of erosion. This figure shows the classic sand bypassing that occurs at many inlets—a buildup of sand (blue accretionary areas) on the east side of the entrance channel and bypassing bars to the south and west of the entrance channel.

Volume Computations. Volume computations only require one additional step. Once elevation changes have been computed between two data sets, the user selects triangles in the area of interest. SHOALS Toolbox will report the volume of the selected triangles. For each triangle, the volume is computed by multiplying the area of the triangle by the average elevation of the three corners of the triangle.

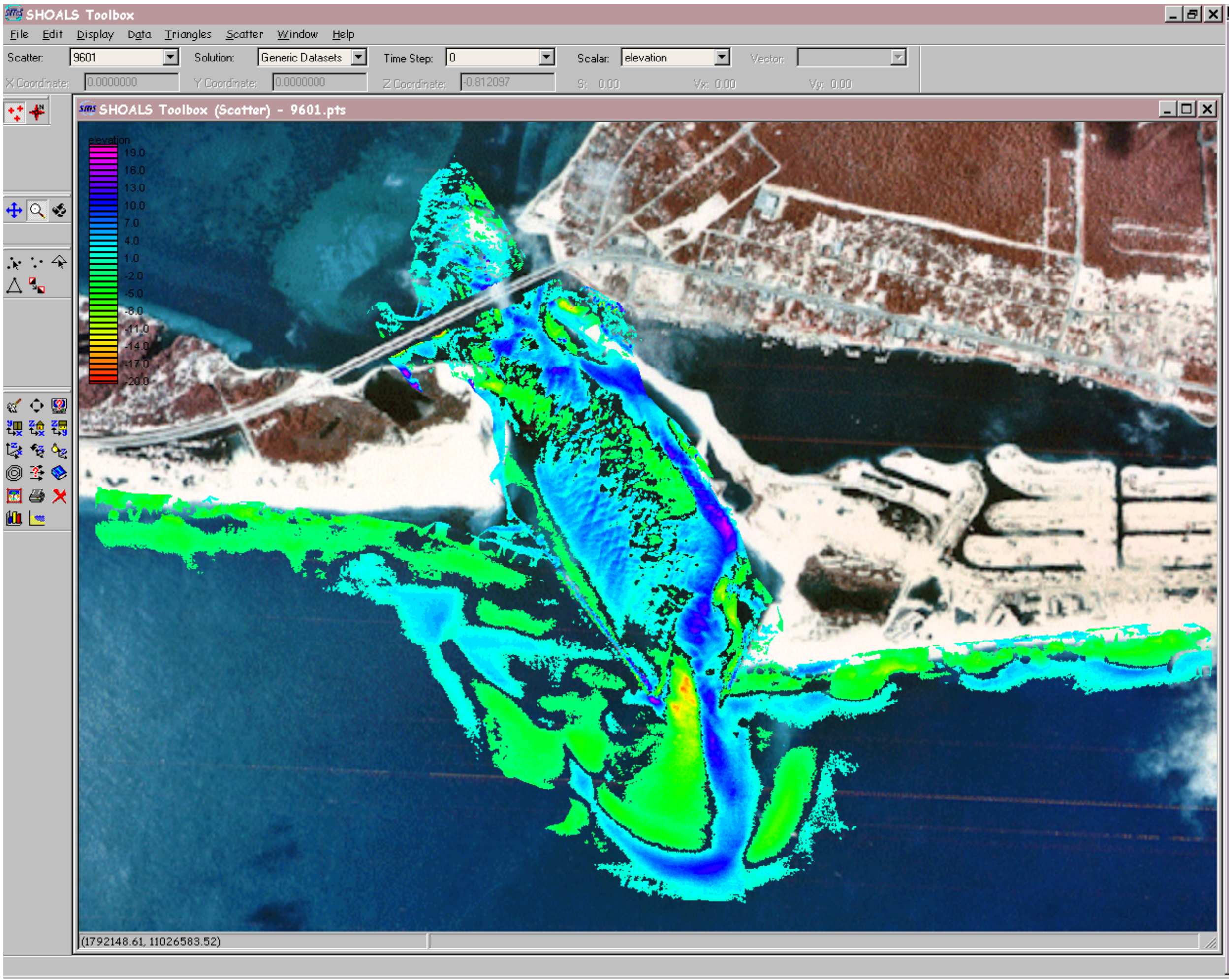
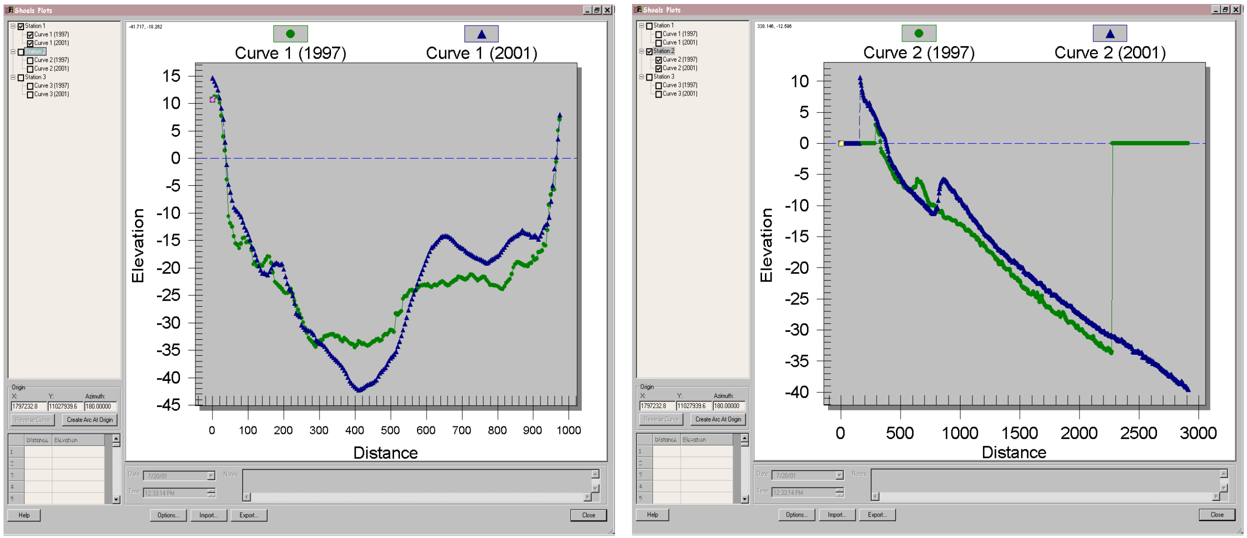


Figure 7. Example of elevation change calculation in SHOALS Toolbox. Blue areas are positive elevation change, or areas of accretion. Green areas are negative elevation change, or areas of erosion

Profile Tool. The Profile tool allows SHOALS data users to cut profiles through SHOALS data for comparison with conventionally collected profile data. There are three methods for profile creation. One of these is manual. For this method the user simply clicks the end points describing the desired location of the profile line. Another method creates profiles along the user-specified shoreline. SHOALS Toolbox extracts the shoreline at a user-specified elevation. The profile creation tool then creates profiles perpendicular to the shoreline at a user-specified spacing. The third method of profile creation is the most flexible, allowing SHOALS data users to enter profile starting location and azimuth. This information can be copied from Microsoft Excel into a spreadsheet-like interface for easy data entry. For each of these profile creation methods, the user is required to enter desired spacing of points along the profile lines. The points along the profile line are where SHOALS Toolbox will interpolate a value from the SHOALS data surface. All interpolating methods are available to the user during profile extraction. Two examples of profile extracted using SHOALS Toolbox are shown in Figure 8. These profiles were extracted from the 1997 and 2001 SHOALS data sets collected at East Pass, FL.



a. Profile extracted between jetties

b. Profile extracted from east beach

Figure 8. Profiles extracted from SHOALS data at East Pass, FL

Imagery Tool. The Imagery tool gives SHOALS data users the capability to load imagery as a background for survey data. SHOALS Toolbox supports import of georeferenced imagery, such as geo-tiffs, and also allows the user to reference unrectified imagery by specifying three known points in the image. All imagery can be reprojected in SHOALS Toolbox and exported as a geo-tiff.

CURRENT AND FUTURE DEVELOPMENT: Currently funded development of SHOALS Toolbox focuses on the compatibility between SHOALS Toolbox and Geographic Information Systems (GIS). In the future SHOALS Toolbox will be available as a GIS extension.

ADDITIONAL INFORMATION: The SHOALS Toolbox is being developed by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) and the Coastal Inlets Research Program (CIRP), Inlet Geomorphology and Channel Evolution Work Unit, U.S. Army Corps of Engineers. SHOALS Toolbox is available free of charge to all U.S. Department of Defense and Department of Energy employees. To obtain a copy of the software please contact Ms. Jennifer Wozencraft of the JALBTCX at *jennifer.m.wozencraft@usace.army.mil* or by telephone (251) 690-3466. For further information about the JALBTCX, please consult the Web site *http://shoals.sam.usace.army.mil* or contact the JALBTCX Director, Mr. Jeff Lillycrop, at *jeff.lillycrop@usace.army.mil* or by telephone (251) 694-3721. For further information about CIRP, please consult the Web site *http://cirp.wes.army.mil/cirp/cirp.html* or contact the CIRP Program Manager, Dr. Nicholas C. Kraus, at *Nicholas.C.Kraus@erdc.usace.army.mil* or by telephone at (601) 634-2016. This CHETN should be cited as follows:

Wozencraft, J. M., Lillycrop, W. J., and Kraus, N. C. (2002). "SHOALS Toolbox: Software to support visualization and analysis of large, high-density data sets," ERDC/CHL CHETN-IV-43, U.S. Army Engineer Research and Development Center, Vicksburg, MS. *http://chl.wes.army.mil/library/publications/chetn/*